IAEA
International Atomic Energy Agency

INDC(NDS)-0555
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INDC International Nuclear Data Committee

Summary Report

Third Research Coordination Meeting on

Development of a Reference Data Base for Ion Beam Analysis

IAEA Headquarters, Vienna, Austria
27 – 30 April 2009

Prepared by

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IAEA Nuclear Data Section
Vienna, Austria

and

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December 2009

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Austria

Printed by the IAEA in Austria
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Abstract

Highlights of the Third and last Research Coordination Meeting are given with respect to the progress achieved in the Co-ordinated Research Project on Development of a Reference Database for Ion Beam Analysis. The meeting took place at the IAEA headquarters in Vienna from 27 March to 3 April 2009. Participants presented the results of their work and identified and assigned key tasks in pursuance of the final output of the CRP, in particular the update of the IBANDL library and the drafting of the final Technical Report of the CRP. In addition, a number of productive discussions took place concerning issues such as measurements, assessments, evaluations, benchmarks and recommendations. The main conclusions as well as lists of responsibilities and tasks towards the production of the final report are presented.

December 2009

TABLE OF CONTENTS

1. Introduction

The Coordinated Research Project (CRP) "Development of a Reference Database for Ion Beam Analysis" was initiated by the IAEA after consultation with the ion beam analysis (IBA) community with the aim to produce a nuclear reaction cross section database containing recommended data of relevance for Ion Beam Analysis. Initially, the duration of the CRP was set at three years. Later on, a one-year extension was granted to allow benchmark experiments to be performed and analyzed. At the first Research Coordination Meeting (RCM) which was held from 23-25 November 2005 participants assembled in order to define the detailed scope of the CRP and identify priority reactions for compilation, assessment and evaluation, including measurement or re-measurement where necessary. The second RCM from 18 – 21 June 2007 was scheduled at that time in order to assess the progress made at the half-way mark and define actions necessary to meet the goals of the CRP. During the second RCM all participants presented summaries of their work for comment and group discussion resulting in the development of a continued coordinated research plan. In the third RCM on 27 – 30 April 2009, the participants presented the results of their work and identified and assigned key tasks required to ensure that the final output of the CRP would be achieved.

At the first RCM it was agreed that special emphasis should first be given to elastic reactions of protons and alphas with light elements, since these reactions are widely used and nuclear theory exists on the basis of which valid evaluations can be made. Deuteron-induced nuclear reactions such as $^{16}O(d,p_n)^{17}O$ were ranked second on the agenda, since application of the underlying nuclear reaction theory for evaluation purposes is substantially complicated by the large number of reaction channels that need to be accounted for. The results presented at this third RCM reflected this choice, with the majority of assessments and evaluations carried out for (α,α) and (p,p) scattering.

The second major activity within this CRP has been the further development of the IBANDL database and harmonisation of experimental data in IBANDL and in EXFOR. This work has been ongoing since before this CRP (see first RCM report INDC(NDS)-0481, January 2006) with a computer code for format conversion and data transfer between these two databases already working in the Web interface, opening the possibility of automation in the future.

This report presents the participants' progress reports (for individual presentations please see http://www-nds.iaea.org/iba/), a synopsis of the conclusions reached after discussion during the meeting, and the tasks and deadlines agreed to by the participants.

2. Meeting Summary

2.1. Opening

The meeting was opened by the then head of the Nuclear Data Section (NDS), A.L.Nichols. D. Abriola gave a brief introduction to the objectives of this RCM and following his nomination, A. Gurbich was elected chairman and I. Vickridge rapporteur by unanimous vote. The preliminary agenda was adopted without changes.

A.L. Nichols and D. Abriola gave an introduction to the possible structure of the final CRP report to be published by the IAEA, and discussed the three possible kinds of publication, the

STI report, the Technical Report Series and the Technical Report. Either of the first two was deemed adequate for the CRP final report.

2.2. Progress Reports on Measurements

The new measurements undertaken by CRP participants were presented at this meeting. I. Bogdanovic presented alpha-induced measurements performed at the Laboratory for ion beam interactions, Division of experimental physics, Ruđer Bošković Institute, Zagreb, Croatia. M. Mayer showed preliminary results for ^{3}He-induced reactions on several targets, work done in collaboration by the Max-Planck-Institut für Plasmaphysik, EURATOM Association, Garching, Germany with the Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences in Moscow. M. Kokkoris presented p and d-induced reactions on a variety of targets, experiments which had been carried out at the Institute of Nuclear Physics, TANDEM Accelerator, N.C.S.R. 'Demokritos', Athens, Greece, in collaboration with the Department of Physics of the National Technical University of Athens, and the Department of Chemistry of Aristotle University Thessaloniki, Greece.

2.2.1. Alpha backscattering cross section from N in the energy region from 2.5 to 4 MeV, I. Bogdanovic

Bogdanovic described the calibration of the analyzing 90° magnet using narrow resonances ^{27}Al(p,γ)^{28}Si at 991.88 keV and neutron threshold reaction ^{7}Li(p,n)^{7}Be at 1880.6 keV as well as the use of secondary calibration points for further checks.
The target was a Si_3N_4 100 nm thick + 6 nm Au.
Data were presented for N(α,α)N at 118°, 150° and 165° in the energy interval: 2.4 to 3.95 MeV, with a minimum step of 5 keV near the resonances and 20 keV elsewhere.

Comments:
Gurbich mentioned that the analyzing magnet calibration could not be linear in NMR, which is for alpha or proton projectiles.
Jeynes suggested that the position of a resonance and its uncertainty should be stated separately.

2.2.2. New measurements of ^{12}C(^{3}He,p)^{14}N, ^{13}C(^{3}He,p)^{15}N and ^{16}O(^{3}He,p)^{18}F reaction cross sections, M. Mayer

Mayer pointed out the advantages of using (^{3}He,p) reactions instead of (d,p) reactions:

- D(d,n)^{3}He reaction causes radiation safety problems when using deuterium beams $\Rightarrow$ much less radiological problems with ^{3}He beams;
- p and d beams are difficult to use intermittently with tandem sputter source (exchange of sputter target);
- D, ^{9}Be, ^{10}B, ^{11}B, ^{12}C, ^{13}C, ^{16}O can be detected simultaneously;
- Depth resolution is often better with ^{3}He than with d-induced reactions;
- Depth profiling until very large depths is often possible with acceptable depth resolution $\Rightarrow$ depth profiling of D down to 40 µm in C was demonstrated (M. Mayer *et al.*, NIM B267 (2009) 506).

However, there are some disadvantages using (^{3}He,p) reaction:

- Many excited states may result in complicated spectra and overlap of peaks;
- Cross-section data almost non-existent or contradicting.

Results were presented for $^{12}C(^{3}He,p_0)^{14}N$, $^{13}C(^{3}He,p_0)^{15}N$ and $^{16}O(^{3}He,p_0)^{18}F$:

- Cross-sections were measured at 135° from 1.2 – 4 MeV;
- No absolute calibration yet, only relative values;
- New samples necessary for absolute calibration.

Comments:
Mayer said that so far he had no absolute calibration and that in the $^{12}C(^{3}He,p_0)^{14}N$ case some discrepancy existed with previous data; plans to measure bulk spectrum to solve discrepancies.

2.2.3. New Nuclear Reaction Analysis (NRA) and Nuclear Backscattering Spectrometry (NBS) measurements on ^{nat}K, ^{nat}Sc, ^{19}F and $^{6,7}Li$, M. Kokkoris

Kokkoris presented the final results of previous experiments (2007-2008) for:

- $^{11}B(d,\alpha_0)$ (d,α_2) (d,p_0) at 140°, 150°, 160° and 170° between 0.9 and 1.2 MeV (200 new data points in IBANDL);
- $^{28}Si(d,p_0)$ (d,p_1) (d,p_2) (d,p_3) at 145°, 150°, 155°, 160°,165° and 170° between 1.2 and 3 MeV (more than 150 new data points in IBANDL);
- $^{14}N(d,p_0)$ (d,α_0) (d,α_1) at 145°, 150°, 155°, 160°, 165° and 170° between 0.9 and 2 MeV (more than 900 new data points in IBANDL).

The new measurements were made with targets of Halogen salt (KF, LiF, $ScBr_3$), analysis is in progress:

- $^{nat}K(p,p_0)$ at 140°, 150°, 160° and 170° between 3 and 5 MeV;
- $^{45}Sc(p,p_0)$ at 140°, 150°, 160° and 170° between 2 and 5.5 MeV;
- $^{6}Li(p,p_0)$ at 135°, 140°, 145°, 150°, 155°, 160°,165° and 170° between 0.9 and 2 MeV.

Regarding NRA, (p,α) reaction studies on $^{6,7}Li$, $^{10,11}B$, ^{19}F and ^{23}Na will be considered in the future. For NBS, (d,d_0) on $^{6,7}Li$, and $^{10,11}B$ and (α,α_0) on ^{31}P, ^{nat}S, ^{39}K and ^{nat}Ca are scheduled in a 5-year plan in order to facilitate the data evaluation process.

Comments:
Kokkoris pointed out that the p + ^{nat}K peak at 4 MeV had been taken 15 days ago, and that it only appeared at 140° but not at other angles; the “depths” in the cross sections, however, were present at all angles.
Gurbich remarked that this looked strange and suggested to look for a possible contamination.

2.3. Progress Reports on Assessments

The assessment tasks included the compilation and critical examination of the previous experimental results, detecting discrepancies and possible errors or omissions in the IBANDL database. When discrepancies are found, a procedure should be suggested to solve them such as using average cross sections or performing a benchmark experiment. The result of the assessment should be a recommendation in the form of a recommended cross section (there could be different recommended cross sections in different energy ranges) or a recommendation to perform new experimental measurements.

2.3.1. Data assessments of the $^{4}He(p,p)^{4}He$ cross sections, Liqun Shi

Liqun presented a table with 12 different excitation functions with the pertinent comments.

Four figures were presented comparing different sets of data at angles between 140° and 170°, and energies between 1.5 and 6 MeV.

Comments:
Liqun pointed out that for ^{4}He(p,p) at 164° data were not in agreement with EXFOR R33 file, neither were they in agreement with SIGMACALC calculation at 2.2 MeV.
Gurbich clarified that there was an error in the SIGMACALC calculation of 2004.

2.3.2. Update of data assessment of ^{12}C(p,p)^{12}C from 3.5 to 5 MeV and ^{12}C(α,α)^{12}C cross sections, I. Bogdanovic

Bogdanovic analyzed the reported databases in IBANDL: five databases for ^{12}C(p,p) differential cross sections in the energy region from 3.5 – 5 MeV.
Data were compared in different figures for 85°, 121°, 138° and 150° between 3 and 6 MeV.
For ^{12}C(α,α)^{12}C, some discrepancies between original data and data published in IBANDL had been detected. It was found that only part of the data from original publications was digitized and transferred to IBANDL database.
Bogdanovic presented a table with 33 entries with 77 different excitation functions with the pertinent comments.
Data were compared in different figures for angles around 135°, 150°, 165° and 170° between 1.5 and 13 MeV.

Comments:
Bogdanovic stressed that for ^{12}C(α,α) there were problems with the agreement at high energies for some angles.
Gurbich said that an evaluation for this reaction was available now.

2.3.3. Progress on assessment of NRA data for light nuclei, M. Kokkoris

Kokkoris analyzed only files that are not included in IBANDL. In principle, this list corresponds to works that meet the general criteria in order to be included in IBANDL, namely scattering angle > 90° and beam energies suitable for ion beam analysis.
Kokkoris presented three tables of excitation functions with the pertinent comments.
One was for ^{10}B(^{3}He,d) (^{3}He,α) (^{3}He,p_x) (d,α) reactions, one for ^{32}S(d,p) and the third for ^{14}N(d,d).

Comments:
Kokkoris said that for some of his reactions a benchmark experiment would be needed to fix the absolute value of the cross section.

2.3.4. Data assessment of ^{14}N(α,$α_0$)^{14}N and ^{14}N(p,p_0)^{14}N cross sections, N. Barradas

Barradas analyzed the data sets in IBANDL which were compared with the original references. A search for other available data was carried out (restricted to 100º-180º scattering angles). All data were compared and checked for discrepancies.
Barradas presented two tables, one with the data already in IBANDL for the ^{14}N(p,p_0)^{14}N reaction with 18 different excitation functions and pertinent comments, and the second with other data with 14 entries and comments. Several figures were presented showing in some cases large discrepancies. Heights and positions of resonances seldom matched with the largest discrepancies appearing in the region around ~1050 keV, ~1750 keV and ~2350 keV were the biggest issues. Some cross sections are higher/lower than most other data sets. Most

of the data is in 150º - 170º region, below 3 MeV. Above 3 MeV and in 125º-145º data are very scarce. Several data sets, previously not in IBANDL, were identified and uploaded. Barradas presented two other tables for the $^{14}N(\alpha,\alpha_0)^{14}N$ reaction. One with the data already in IBANDL having 12 different excitation functions with the pertinent comments, and the second with other data with 4 entries and comments. Several figures were presented comparing the different sets of data. In general, data are very close to Rutherford up to 2.5 MeV (not much data available). Most of the data is in the 160º - 170º region, between 3 and 9 MeV. Above 3 MeV and in the 125º-150º region data are very scarce. Several data sets previously not in IBANDL were identified and uploaded.

Comments:
Barradas said that they would do a benchmark experiment for protons.

2.3.5. Assessment of deuteron-induced nuclear reaction cross sections for analysis of ^{13}C and ^{15}N by ion beams, I. Vickridge.

^{13}C. After discussion of the analytical potential and previous IBA interest in $^{13}C(p,p_0)^{13}C$, $^{13}C(\alpha,\alpha_0)^{13}C$, $^{13}C(p,\alpha)^{10}B$, $^{13}C(d,p_0)^{14}C$, and $^{13}C(d, \alpha_n)^{11}B$ reactions, Vickridge concluded that the highest priority for evaluation should be given to $^{13}C(d,p_0)^{14}N$. This reaction has a large positive Q-value with useable intensity at deuteron energies below 2 MeV, and it is possible to obtain interference-free p_0 peaks in a number of cases of analytical interest (e.g. thin films on silicon). This reaction is of primary interest for analysis. There are two main datasets (both in IBANDL) and where they overlap, they agree within experimental error. A second priority (probably not feasible within the framework of the CRP) is suggested for evaluation for $^{13}C(d,\alpha_n)^{11}B$ for which the high Q-value of 5168 keV suggests possible use in IBA although there is no documented use of this reaction for IBA.

^{15}N. After discussion of the analytical potential and previous IBA interest in $^{15}N(p,p_0)^{15}N$, $^{15}N(\alpha,\alpha_0)^{15}N$, $^{15}N(p,\alpha)^{12}C$, $^{15}N(d,p_0)^{16}O$, and $^{15}C(d,\alpha_0)^{13}C$ reactions, Vickridge concluded that the highest priority for evaluation should be given to $^{15}N(d,\alpha_0)^{13}C$. There is substantial disagreement amongst the sparse early measurements and also between the early measurements and the more modern measurements made in the IBA community. The two most extensive and recent measurements show good agreement.

Comments:
In view of the limited resources available for developing appropriate nuclear models it will not be realistic to include either the $^{13}C(d,p_0)^{14}N$ or the $^{15}N(d,\alpha_0)^{13}C$ reactions in SigmaCalc in the framework of this CRP. For these reactions a recommended cross section derived from the measured cross sections is required. For $^{13}C(d,p_0)^{14}N$ Vickridge proposed recommendation of the data of Colaux *et al*. and for $^{15}N(d,\alpha_0)^{13}C$ the data of Vickridge *et al.* In both cases benchmark experiments are desirable in order to underpin the recommendation. (see task list, year 4). Also to be noted that Chiari is updating the assessment.

2.3.6 Round table for Assessment

It was decided that Mayer would collect the different assessments, put them in a common format and write the assessment chapter of the CRP technical report. Gurbich remarked that the result of every assessment should be a RECOMMENDATION, in the IBANDL library the comments in the beginning of the file should be used to describe why the data are recommended, and if possible some estimation of the uncertainties should be included. In cases where the recommended data is an average of several files or include an energy shift, a new file should be created, indicating the steps taken to produce the recommended cross section from the data files.

2.4. Progress Reports on Evaluations, A. Gurbich

The evaluations were carried out by A. Gurbich. The evaluation of cross sections for any particular reaction consists in the elaboration of a predicted cross section, taking into account experimental data as well as nuclear structure data such as information on the positions, spin and parity of the nuclear energy levels. The predicted cross section is evaluated in the framework of nuclear physics theory.

A. Gurbich reviewed the evaluations carried out between the 2nd RCM and 3rd RCM.

1. For Carbon
   C(d,d): evaluation completed up to 2,0 MeVwith good agreement with data.
   C(p,p): extended to 4.5 MeV.
2. For Nitrogen
   N(p,p): evaluation for energies up to 5 MeVwith good agreement at backward angles (150° and 165° and deviating a little more at 118°).
3. For Oxygen
   O(d,d): evaluation up to 2,1 MeV.
   O(d,p_0): evaluation up to 1.8 MeV, and O(d,p_1) up to 1.1 MeV.
4. For Fluorine
   ^{19}F(p,p): evaluation up to 1.8 MeV.
5. For Neon
   ^{20}Ne(p,p): evaluation up to 2.6 MeV.
6. For Sodium
   ^{23}Na(p,p): evaluation up to 1.5 MeV.
7. For Magnesium.
   ^{24}Mg(α,α): evaluation up to 3.8 MeV.
8. For Phosphorus.
   ^{31}P(p,p): evaluation up to 2.0 MeV.
9. For Argon
   ^{40}Ar(p,p): evaluation up to 2.8 MeV.
10. For Potassium.
    ^{39}K(p,p): evaluation up to 2.3 MeV.
11. For Calcium.
    ^{nat}Ca(p,p): evaluation up to 2.9 MeV.
12. For Titanium
    ^{48}Ti(p,p): evaluation up to 2.5 Mev.

It was the general consensus that in all cases where an evaluation existed, it should be considered the recommended cross-section.

2.5. Progress Reports on Benchmark Experiments

In almost all cases, cross sections are measured using thin film samples: such measurements are difficult, errors can creep in resulting sometimes in discrepant data coming from different measurements. Benchmark experiments measure spectra from a thick sample of known composition. A simulation code is used with one cross section (which may be measured or evaluated) as input and the result is compared with the experimental benchmark, thus demonstrating how good the input cross section (be it measured or evaluated) is to predict the thick target results.

2.5.1. Bulk Method applied to the $^{14}N(p,p_0)$ and $Li(p,p_0)$ cross sections, N. Barradas

The preliminary results of the Bulk Method applied to the $^{14}N(p,p_0)$ cross section at 140° were presented.

For the measurement and benchmarking of the $Li(p,p_0)Li$ cross sections in the 500-2200 keV energy range using bulk samples: The sample was a LiF single crystal, implanted with 300 keV Ar^{2+} and with a deposited $62.0(1.2)x10^{15}$ Au/cm^2 top layer. 15 RBS spectra were measured using protons in the 999 -2200 keV interval, the spectra were acquired at 140º and 160º scattering angles. One problem is that the Li is seen, but superimposed to F. Furthermore, the F has non-Rutherford cross section and there are (p,p') reactions to consider. So the first aim is to start by determining the F cross section. To do that, the point by point method is used: each data point is converted into a cross section value, the calculated stopping is used to determine the energy of interaction. The superposition of signals is solved by calculating and subtracting the signals from other elements, as a result the F data is well separated.

2.5.2. Benchmark for the $^6Li(d,\alpha_0)^4He$ reaction, M. Kokkoris

Kokkoris presented their new benchmark for the $^6Li(d,\alpha_0)^4He$ reaction, at the energy of 2000 keV and 150°.

The target was $LiAlO_2$ in crystal form. The target was randomly rotated to minimize possible channelling problems. The results were in agreement with Gurbich evaluations. The differential cross section values were verified with an accuracy of 5-7%. New benchmarking experiments are scheduled for September 2009.

2.5.3. Benchmark for the p + ^{23}Na and p + ^{12}C elastic scattering cross sections, M. Chiari

All measurements were performed at the 3 MV Tandetron accelerator of INFN-LABEC laboratory in Florence.

a) P + ^{23}Na

The target was a commercial glass sample (ca. 4%, Si 30%, Na 11%, O 55%), coated with thin Ti (75 nm) and Au (145 nm) layers. Target composition was determined by RBS analysis with 2.0 MeV α-particles.

The detector was a Si PIN diode (300 mm thick, 100 mm^2 area), 17 keV FWHM energy resolution, dead layer 1600 10^{15} at/cm^2 Si. It was placed at 150°, normal incidence (IBM geometry). The detector aperture was 3 mm width x 6 mm (@ 61 mm from target).

The proton beam energies were 3.20, 2.90, 2.50, 1.47 and 1.27 MeV and the beam intensity about 5 nA (which represented a dead time < 5%).

Typical measurement times: 600–900 s. Data were analysed with SIMNRA v.6.40, using SRIM2003 stopping powers.

IBANDL cross section used:

- p + O *from SigmaCalc 1.6*;
- p + Si *from Amirikas et al., NIM B77 (1993) 110;*
- p + Ca, p + Ti and p + Au are assumed to be Rutherford.

b) P + ^{12}C

The target was a Sigradur glassy carbon sample, mechanically cut and then polished.

The detector was a Si PIN diode (300 mm thick, 100 mm^2 area), 20 keV FWHM energy resolution, dead layer 1600 10^{15} at/cm^2 Si. It was placed at 150°, normal incidence (IBM geometry). The detector aperture was 3 mm width x 6 mm (@ 61 mm from target).

The proton beam energies were 4.849, 4.899, 4.988 and 5.098 MeV and the beam intensity: 2.2 - 2.4 nA (which represented a dead time 8-9%) Typical measurement time: 500-600 s. Data were analysed with DataFurnace NDF v9.2a, using SRIM2003 stopping powers, taking into account resonance effect, pile-up and double scattering.

c) Future measurements

Benchmark test experiments of the p + ^{10,11}B elastic scattering cross sections at several energies and several scattering angles using a B_4C thick sample are planned to be performed at the 2 MV Tandem accelerator of IMM-CNR, Bologna, in collaboration with Marco Bianconi.

2.6. Progress Reports on Recommended Cross Sections

It was generally agreed that wherever evaluated cross sections were available, those would be the recommended cross sections. In those cases where discrepant cross-section measurements existed, the task of the assessment would be to produce a final recommendation, wherever possible. If no recommendation was possible, the user would find in the IBANDL database all the available cross sections for this and he would be able to follow all the relevant discussions and comparisons in the final technical report.

2.7. Proposal of a follow-up CRP on PIGE data for IBA

The results achieved so far have shown that, by coordinated efforts in a CRP framework, great progress in the sometimes problematic assembly of recommended nuclear cross section data for IBA can be achieved.
A significant number of particle-induced gamma-ray emission (PIGE) cross section data, which fall outside the scope of the present CRP, have been uploaded to IBANDL by members of the IBA community other than participants of the CRP. In doing so, the IBA community has shown that there is an overwhelming need for compilation, assessment and evaluation of PIGE data. Thus, the constitution of a new CRP would certainly further and accelerate concerted efforts to that end. The proposed new CRP could benefit from the experience of those present members with appropriate PIGE expertise, which would be reinforced by participation of new members chosen for their specific PIGE expertise. It is suggested that a Consultants' meeting be held in 2010 to assess the needs and scope of such a new CRP.

3. Actions

3.1. Assignment of Chapters for Final Report

Introduction/Conclusion	Vickridge
IBANDL (+R33 format, EXFOR link, Sigmacalc, CD version)	Gurbich, NDS
Assessments	Mayer
Measurements	Bogdanovic
Elaboration of recommended data	Mayer-Gurbich
Evaluations	Gurbich

3.2. Updated List of Basic and Assessment Tasks at the 3rd RCM (April 2009)

Name	Basic tasks	Assessment tasks
Bogdanovic-Radovic	**Year 1:** 1. Determine energy and angular ranges where new measurements are most urgently needed. 2. Preparation of target and scattering chamber for the experiment. 3. Detector calibration by measuring scattering chamber and detector solid angles. 4. Measure the N(p,p) non-Rutherford elastic scattering cross section up to 5 MeV and provide results to IBANDL. **Year 2:** 1. Measure the O(p,p) and Al(p,p) non-Rutherford elastic scattering cross section up to 5 MeV and provide results to IBANDL. 2. Measure the N(α,α), and Si(α,α) non-Rutherford elastic scattering cross section between 2 and 8 MeV and provide results to IBANDL. **Year 3:** Analysis of data for N(α,α)N non-Rutherford cross sections. Preparation of chapter about measurements for the final CRP report. **Year 4:** Creation, if possible, of recommended cross sections for ^{16}O(d,α) reaction. Send BN target and results for N(p,p) to Jeynes. Finish chapter about measurements for final CRP report.	^{nat}C(p,p) 3.5 to 5 MeV, (α,α) up to 8 MeV
Chiari	**Year 1:** Install and test the multiple-detector scattering chamber. **Year 2:** Measure N(p,p) elastic scattering cross section at energies up to 6 MeV as function of scattering angle. **Year 3:** Measure C(p,p) elastic scattering cross section in energy range 3 – 6 MeV as a function of scattering angle. Measure F(p,p) and Li(p,p) elastic scattering cross sections at energies up to 6 MeV as a function of scattering angle. **Year 4:** Measure and include results in IBANDL: ^{7}Li(p,p), ^{12}C(p,p), ^{19}F(p,p) elastic cross sections in the 3 – 7 MeV energy range; the ^{23}Na(p,p) elastic cross sections in the 2.2 – 5.2 MeV energy range; the ^{19}F(p,p') inelastic cross sections in the 3 – 7 MeV energy range and the 4.808 MeV resonance in the ^{12}C(p,p)^{12}C elastic cross section. Benchmark test experiments of the ^{23}Na(p,p) elastic cross section up to 3.2 MeV, the ^{12}C(p,p) elastic cross section in the 4.8 – 5.1 MeV range, the ^{10,11}B(p,p) elastic cross section up to 3 MeV, and the ^{12}C(p,p) elastic cross sections up to 4.5 MeV. Produce plots of energy at which the elastic scattering cross section deviates from Rutherford as a function of target for p and α projectiles using evaluated data. (Disclaimer: The basic task list was changed due to technical problems in the installation of the multiple-detector scattering chamber at the new accelerator laboratory within the proposed time schedule).	^{23}Na(p,p) ^{19}F,^{7}Li,^{6}Li(p,p)

Gurbich	**Year 1:** 1. Search literature and include 20 additional works in IBANDL database. 2. Evaluate differential cross sections for elastic scattering of alphas on O and Si, based on critical assessment of existing experimental data and on nuclear model calculations, and supply the results in tabular form to NDS. 3. Measure the differential cross section of (d,p) and (d,α) reactions on Al, as well as the thick-target gamma-ray yield on Al, in the energy range 1 to 2 MeV, and include the new data in IBANDL. *(All tasks completed except for evaluation of Si(α,α))* **Year 2:** 1. Continue support for IBANDL database by adding new data sets from literature or supplied by authors and by including improvements of database structure. 2. Evaluate differential cross sections for elastic scattering of protons on N, based on critical assessment of existing experimental data and on nuclear model calculations, and supply the results in tabular form to NDS 3. Measure the differential cross section of (d,p) and (d,α) reactions on N in the energy range from 1 to 2 MeV with an energy step of 20 KeV, and include the new data in IBANDL. *(All tasks completed)* **Year 3:** 1. Continue support for IBANDL database by adding new data sets from literature or supplied by authors and by including improvements of internal structure of database. 2. Extend evaluation of differential cross sections for elastic scattering of protons on N to energy range 3.5 – 5 MeV. 3. Evaluate differential cross sections for elastic scattering of protons on ^{10,11}B and F. 4. Extend evaluation of C(p,p) to 4.5. MeV (added at 2nd RCM). *(All tasks completed except for evaluation of ^{10,11}B(p,p), some additional evaluations were carried out which were not listed in the tasks (see last slide of the presentation at 3rd RCM))* **Year 4:** 1. Continue support for IBANDL database by adding new data sets from literature or supplied by authors and by including improvements of internal structure of database. 2. Evaluate differential cross sections for elastic scattering, as needed.	^{nat}C, ^{nat}O (d,p) (d,α)
Jeynes	**Year 1:** Measure and evaluate Mg(p,p). Experiment up to 4 MeV at 2 angles as a benchmark. *(Completed and published)* **Year 2:** Measure and evaluate Si(α,α**)**. Experiment at 2 angles. Extract cs from bulk target data using Bayesian Inference (BI). Evaluate stopping cs using Sb implanted ref. Standard from IRMM Geel. Measure Ti(α,α**),** V(α,α**)** and ^{14}N(α,α**)** up to 6 MeV at 2 angles from bulk targets using BI. *(Si(α,α) measured, but BI cannot be used reliably on this data. Ti(α,α), V(α,α), ^{14}N(α,α) not completed)* **Year 3:** Measure Ti(p,p), V(p,p) and ^{14}N(p,p) to 4 MeV at 2 angles from bulk targets using BI. *(Not completed)* **Year 4:** Benchmarks on ^{11}B,^{10}B,^{14}N(α,α).	

Kokkoris	**Year 1:** Measure $^{10,11}B(d,p)$ and (d,α) reactions (on natural and enriched targets) at 8 angles from 900 to 2000 keV. *(Completed)* **Year 2:** Measure $^{14}N(d,p)$, (d,α), (d,d). *(All completed except (d,d))* **Year 3:** Measure $^{19}F(d,p)$, (d,α), $^{6}Li(d,p)$,(d,α). *(All completed)* **Year 4:** $^{7}Li(d,\alpha)$ from 0.9 – 2 MeV, $^{45}Sc(p,p)$ from 2 – 5.5 MeV, $^{nat}K(p,p)$ from 3 – 5 MeV, $^{39}K(p,\alpha_0)$ from 3 – 5 MeV, $^{32}S(d,p)$ from 1.5 – 2.5 MeV. Benchmarks on as many as possible NRA data for $^{10,11}B$, ^{6}Li, ^{32}S, and EBS data for ^{45}Sc, ^{nat}K, ^{nat}Fe, ^{nat}Cr and ^{nat}Ti.	$^{10,11}B$, ^{6}Li, ^{7}Li (d,p) (p,α) (d,α), ^{14}N, ^{19}F (d,p), (d,α), ^{nat}S (NRA) *(completed)*
Lopes Ramos, Pesoa-Barradas	**Year 1:** 1. Obtain appropriate samples and perform detailed compositional analysis by PIXE and RBS. 2. Measure N(p,p) elastic cross section by thin film technique in energy range 500 – 2500 keV at scattering angles 130° - 160° in 10° steps. 3. Develop and validate "bulk sample method" for proton elastic scattering cross-section measurements. 4. Apply bulk sample method to measurement of Li(p,p) elastic scattering cross section. **Year 2:** 1. Perform reproducibility tests for $^{14}N(p,p_0)^{14}N$ cross sections measured during the first year using thin films. 2. Application of the previously developed algorithm to the determination of $^{14}N(p,p_0)^{14}N$ cross sections using a bulk nitride sample and comparison of results with the thin film measurements of the first year. 3. Benchmarking of evaluated/measured (p,p) cross sections in the 500 – 2500 keV range for C, N and Si using standard bulk samples. *(All completed except Si data)* **Year 3:** 1. Perform reproducibility tests for the Li(p,p) cross sections measured during the first and second year. 2. Finalize the benchmarking of evaluated/measured N(p,p) and C(p,p) cross sections in the energy range 500-2500 keV. *(For C the benchmarking was made on the measured cross sections, this is published in NIMB (proc. IBA 2007))* **Year 4:** Finalize ^{nat}Li benchmark on bulk $LiNbO_3$ sample. Made benchmark of Cr,Fe,Ti(p,p) cross section. Modify assessment of $^{14}N(\alpha,\alpha)$ as necessary, including new data recently available.	^{nat}N (p,p) (α,α)
Mayer	**Year 1:** Identify most important cross sections for incident p, d, He-3 and alpha particles for backscattering, elastic recoil analysis, and nuclear reactions *(Completed).* **Year 2:** Analysis and synthesis of assessments from participants, and preparation of manuscript for submission to international journal. *(Assessments collected, synthesis under way)* **Year 3:** Assessment of the existing data (experimental and theoretical) for incident ^{3}He, alphas and heavier ions. *($^{12}C(^{3}He,p)^{14}N$, $^{13}C(^{3}He,p)^{15}N$ and $^{16}O(^{3}He,p)^{18}F$ assessed. First measurements of $^{12}C(^{3}He,p_0)^{14}N$, $^{13}C(^{3}He,p_0)^{15}N$ and $^{16}O(^{3}He,p_0)^{18}F$ at 135°)* **Year 4:** Assessment of Be(p,p), Be(α,α) and Be$(^{3}He,p)$ reactions.	B(p,p) and (α,α) *(completed)* Be(p,p) and (α,α) Be, B, ^{nat}C, ^{nat}O, D $(^{3}He$,charged particle)

Rauhala	**Year 1:** Measure O(α,α) at 7-9 MeV over wide angular region. . **Year 2:** Measure D(p,p) at 0.5-1 and 2-4 MeV at several angles > 100° in cooperation with Vickridge and Mayer. **Year 3:** Measure nuclear reactions of ^{3}He + d system.	D(p,p) B(p,p) and (α,α)
Shi	**Year 1:** 1. Measurement of the differential elastic scattering cross section of alphas incident on D and T in the energy range 3 – 8 MeV at scattering angle of 30°. 2. Measurement of the differential elastic scattering cross section of protons incident on D and T in the energy range 1 – 3 MeV at scattering angles of 151 and 165°. *(Completed)* 3. Provide results to IAEA Nuclear Data Section in tabular form for inclusion to IBANDL database. **Year 2:** Measurement of the differential elastic scattering cross section of alphas incident on D and T in the energy range 3 - 8 MeV at scattering angle of 20° and 40°. *(The work on D,T(α,α) has not been finished because of difficulties preparing the thin target TiD(T) with high concentration)* **Year 3:** - **Year 4:** New measurement ^{4}He(p,p) at 165° and 150°. Benchmark on ^{4}He(p,p) at energies from 1.2 – 3.0 MeV at 165° and 150°. Recommend cross sections for ^{4}He(p,p) and D,T(p,p).	D,T (α,α), (p,p) ^{4}He(p,p) *(all completed)*
Vickridge	**Year 1:** Identification of most important reactions based on needs for NRA and feasibility of measurements, and identification of optimal energy and angular ranges, with input from first RCM. Preparation of trial targets and tests of target stability under the beam. Evaluation of interferences from parasite reactions. *(Completed)* **Year 2:** Measurement of cross sections for deuteron-induced reactions on ^{13}C, and inclusion of results in IBANDL. Preparation of thin ^{15}N films for measurements in Year 3. *(Not completed, no longer necessary since new measurements from Colaux et al. published)* Measure D(p,p) at 1-2 MeV at several angles > 100° in cooperation with Rauhala and Mayer. *(Not completed, target produced and sent to Rauhala)* **Year 3:** Measurement of cross sections for deuteron-induced reactions on ^{15}N, and inclusion of results in IBANDL. **Year 4:** Benchmark experiment for Calaux et al. data for ^{13}C(d,p_0) feasible, plus measurement if feasible (see year 4 task list). After assessment, it is concluded that a benchmark experiment is desirable, however, reliable thick target of adequate homogeneous composition remains to be fabricated. This may not be achieved during the CRP. With respect to final report: Write Introduction and IBANDL section with Gurbich. Send ^{13}C(d,p_0) and ^{15}N(d,p_0) assessments to Mayer. Attempt ^{13}C(d,p_0) Benchmark for 150°, 0 – 1.5 MeV.	^{13}C, ^{15}N (p,p) (α,α) (d,p) (p,α) (d,α)

Appendix 1

International Atomic Energy Agency
3rd Research Co-ordination Meeting on

Development of a Reference Database for Ion Beam Analysis

IAEA Headquarters, Vienna, Austria
27-30 April 2009
Meeting Room A0478

AGENDA (draft)

Monday, 27 April

08:30 – 09:30	**Registration (IAEA Registration Desk, Gate 1)**
09:30 – 10:15	**Opening Session** Opening Remarks and Welcome (A.L. Nichols) Introduction: Objectives of this RCM (D. Abriola) Election of Chairman and Rapporteur Discussion and Adoption of the Agenda (Chairman) Explanation of Technical Report: scope, format, authorship, etc. (A.L Nichols, D. Abriola)
10:15 – 11:00	*Coffee break and Administrative Matters*
11:00 – 12:30	**Progress Reports on Measurements** 1) Alpha backscattering cross section from N in the energy region from 2.5 to 4 MeV, I. Bogdanovic (15 min) 2) New measurements of $^{12}C(^{3}He,p)^{14}N$, $^{13}C(^{3}He,p)^{15}N$ and $^{16}O(^{3}He,p)^{18}F$ reaction cross sections, M. Mayer (15 min) 3) New NRA and NBS measurements on ^{nat}K, ^{nat}Sc, ^{19}F and $^{6,7}Li$, M. Kokkoris (20 min) 4) Roundtable discussion *Coffee break as needed*
12:30 – 14:00	*LUNCH*
14:00 – 17:30	**Progress Reports on Assessments** 1) Data assessments of the $^{4}He(p,p)^{4}He$ cross sections, Liqun Shi (20 min) 2) Update of data assessment of $^{12}C(p,p)^{12}C$ from 3.5 to 5 MeV and $^{12}C(\alpha,\alpha)^{12}C$ cross sections, I. Bogdanovic (15 min) 3) Progress on assessment of NRA data for light nuclei, M. Kokkoris (10 min) 4) Deuteron-induced reactions on ^{13}C and ^{15}N, I. Vickridge (15 min) 5) Data assessment of $^{14}N(\alpha,\alpha_0)^{14}N$ and $^{14}N(p,p_0)^{14}N$ cross sections, N. Barradas (30 min) 6) Updating the assessments on elastic scattering cross section of protons on ^{7}Li, ^{19}F and ^{23}Na, M. Chiari (10 min) 7) Roundtable discussion *Coffee break as needed*

Tuesday, 28 April

09:00 – 12:30 **Progress Reports on Evaluations**

1) New results in the evaluation of the cross sections, A. Gurbich (20 min)
2) Roundtable discussion

Progress Reports on Benchmark Experiments

1) Cross-section value testing for ^{28}Si and $^{6,7}Li$, M. Kokkoris (10 min)
2) Measurement and benchmarking of the (p,p_0) cross sections for natural lithium in the 500-2500 keV energy range using bulk samples, N. Barradas (15 min)
3) Benchmark test experiments of the $p+^{23}Na$ and $p+^{12}C$ elastic scattering cross sections, M. Chiari (10 min)
4) Roundtable discussion

Progress Reports on Recommended Cross Sections

1) $^{16}O(d,p)$ and $^{16}O(d,\alpha)$, I. Bogdanovic (5-10 min)
2) Roundtable discussion

Coffee break as needed

12:30 – 14:00 *LUNCH*

14:00 – 17:30 **Review of Tasks from 2nd RCM**

New Task List

List of reactions for final database

IBANDL Status Report (A. Gurbich)

General discussion

Coffee break as needed

19:00 ***DINNER at the Restaurant "Zur alten Kaisermühle"***

Wednesday, 29 April

09:00 – 12:30 **Recommended Cross Sections for IBANDL**

General discussion

Coffee break as needed

12:30 – 14:00 *LUNCH*

14:00 – 17:30	**Final CRP report** (Technical Report)	
	a) Introduction b) Measurements (review and additions) c) Assessments d) Evaluations e) Recommended cross-sections f) Conclusions	
		Coffee break as needed

Thursday, 30 April

09:00 – 12:30	**Time frame for final document and final release of IBANDL** Deadlines for tasks	
	Summarize results of RCM	
	Review of tasks and conclusions	
		Coffee break as needed
12:30 – 14:00	*LUNCH*	
14:00 – 16:30	**Drafting of the 3rd RCM Summary Report**	
16:30	**Closing of the meeting**	

3rd Research Coordination Meeting on
"Development of a Reference Database for Ion Beam Analysis"
27 to 30 April 2009

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